Sixth Annual Conference on Carbon Capture & Sequestration

Geologic Storage-MMV (1)

Monitoring spatio-temporal variability of surface CO_2 emissions at the Horseshoe Lake tree kill, Mammoth Mountain, CA

Jennifer L. Lewicki, George E. Hilley, Marc L. Fischer, Toshi Tosha, Ryosuke Aoyagi, Koji Yamamoto, and Sally M. Benson

May 7-10, 2007 • Sheraton Station Square • Pittsburgh, Pennsylvania

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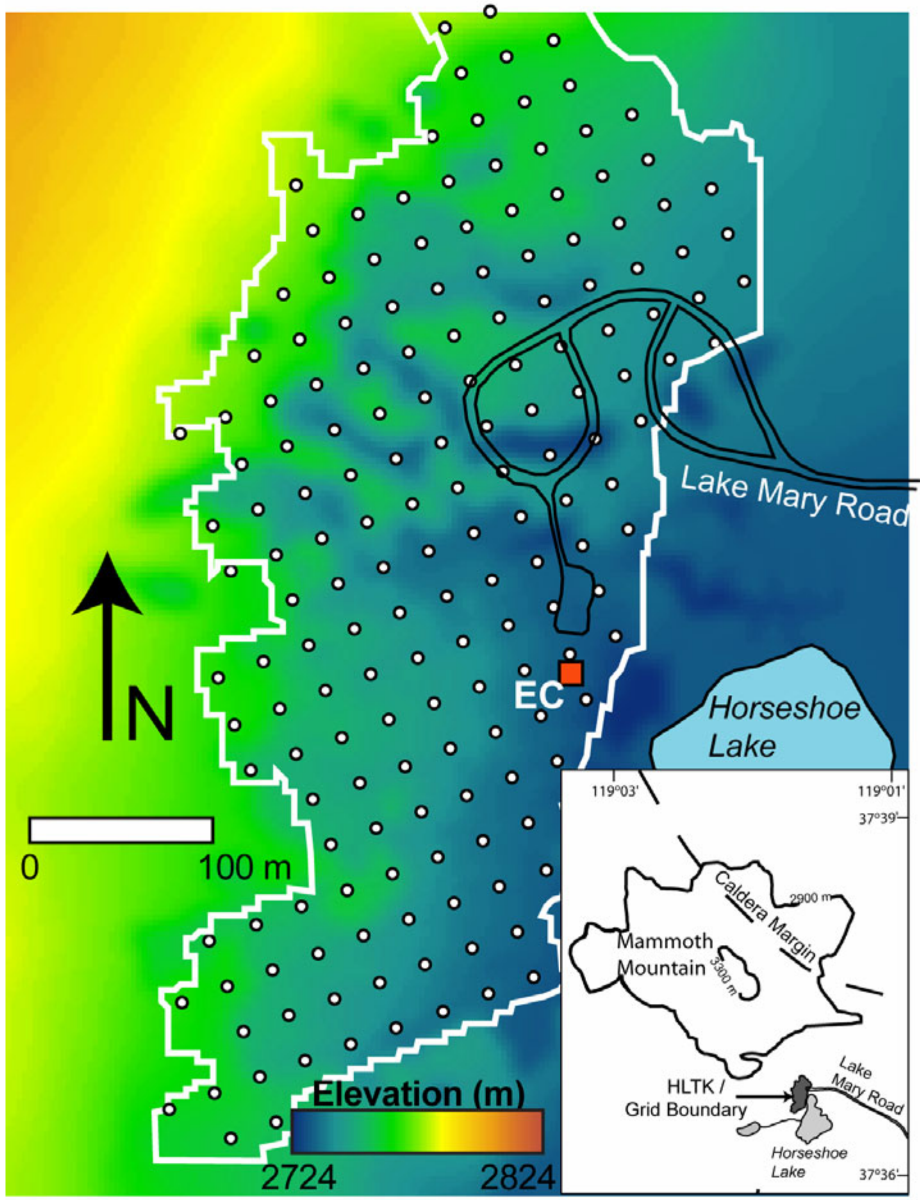
Motivation

- Mammoth Mountain studied as a natural analogue for large CO_2 leakage events
- Investigate spatio-temporal variability of soil CO_2 fluxes and relationship to meteorological parameters and topography using chamber method
- Compare chamber and eddy covariance CO_2 flux measurements at challenging site

Recent Activity

Study Site

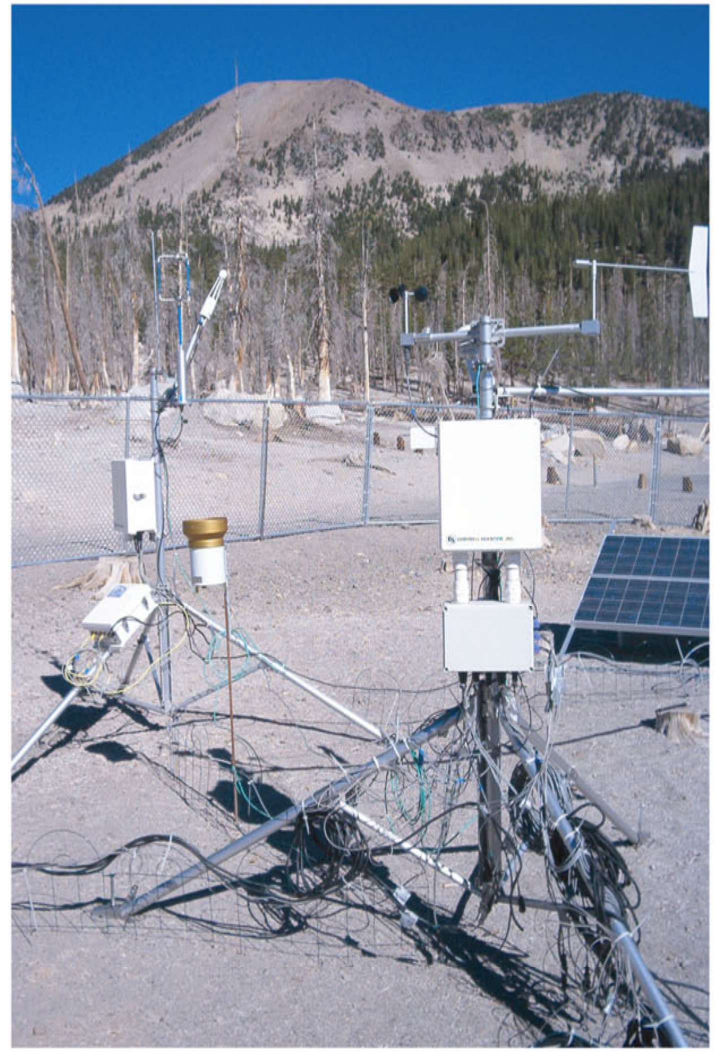


Lake Mary Road
EC
Horseshoe Lake
N
0
100 m
Elevation (m)
2724
2824
119°03'
119°01'
37°39'
Caldera Margin
2900 m
Mammoth Mountain
3300 m
HLTK / Grid Boundary
Lake Mary Road
Horseshoe Lake
37°36'

Chamber Soil CO_2 Fluxes

Eddy Covariance Net Surface CO_2 Flux

$F_c = \overline{w'c'}$

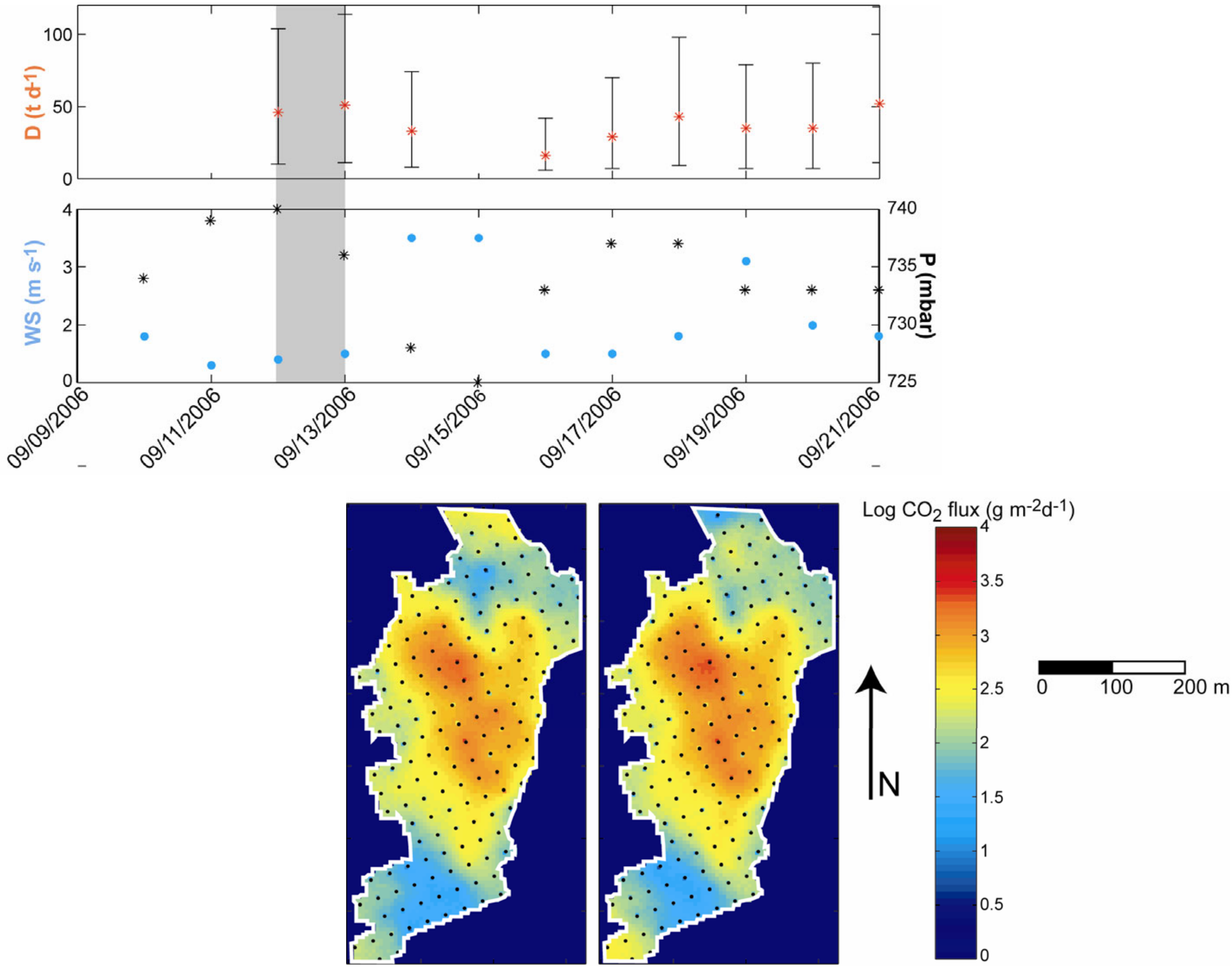


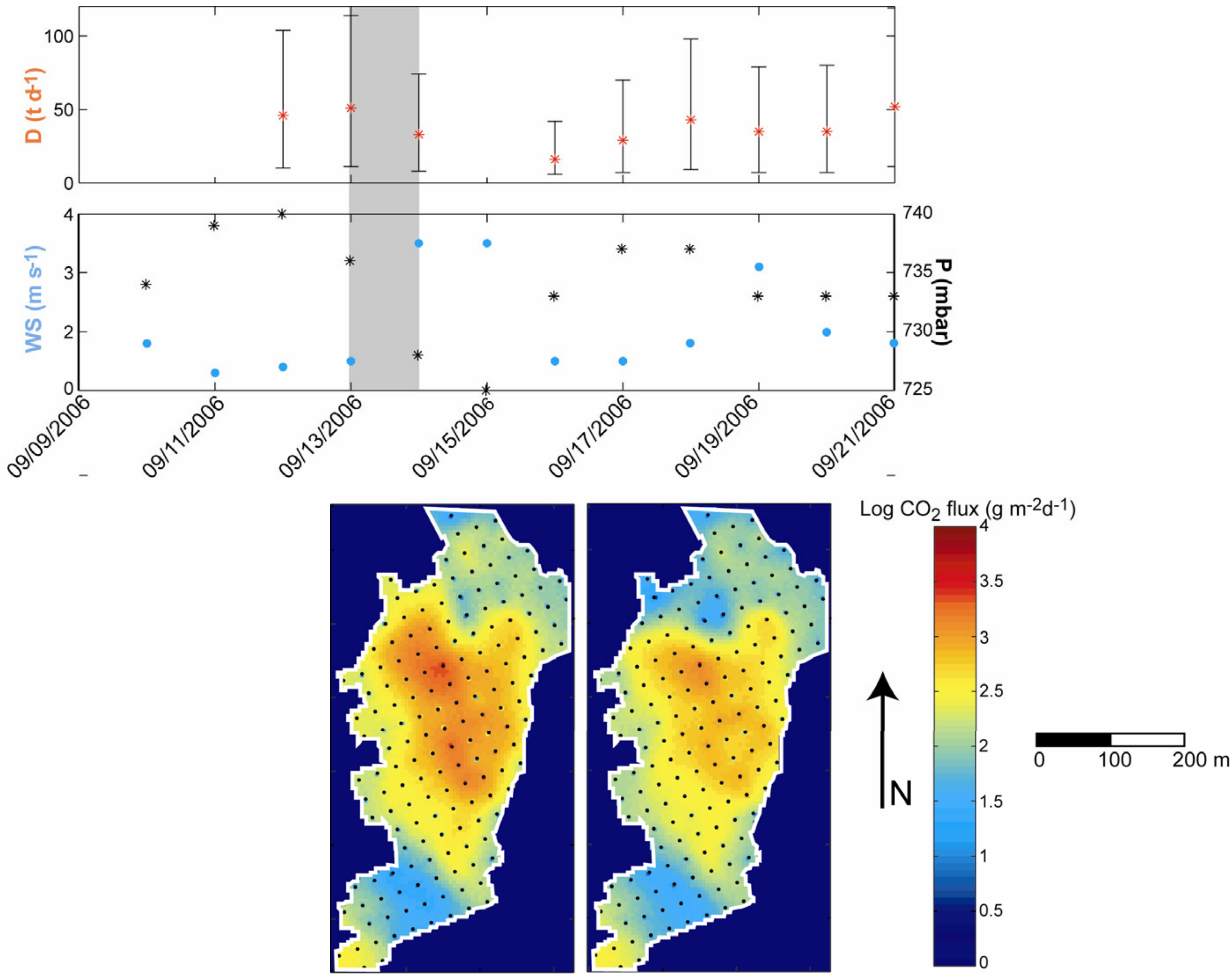
- Requires sufficiently long averaging time, steady-state conditions; assumes homogeneous surface

- Data filterered for systematic errors

- F_c is integral of surface flux over upwind footprint (m^2-km^2 scale) that scales with measurement height

-Additional parameters: Atmospheric pressure, temperature, radiation, and humidity, soil temperature, moisture, and heat flux


D (t d-1)
100
50
0
WS (m s-1)
4
3
2
1
0
P (mbar)
740
735
730
725
09/09/2006
09/11/2006
09/13/2006
09/15/2006
09/17/2006
09/19/2006
09/21/2006
Log CO2 flux (g m-2d-1)
4
3.5
3
2.5
2
1.5
1
0.5
0
N
0
100
200 m



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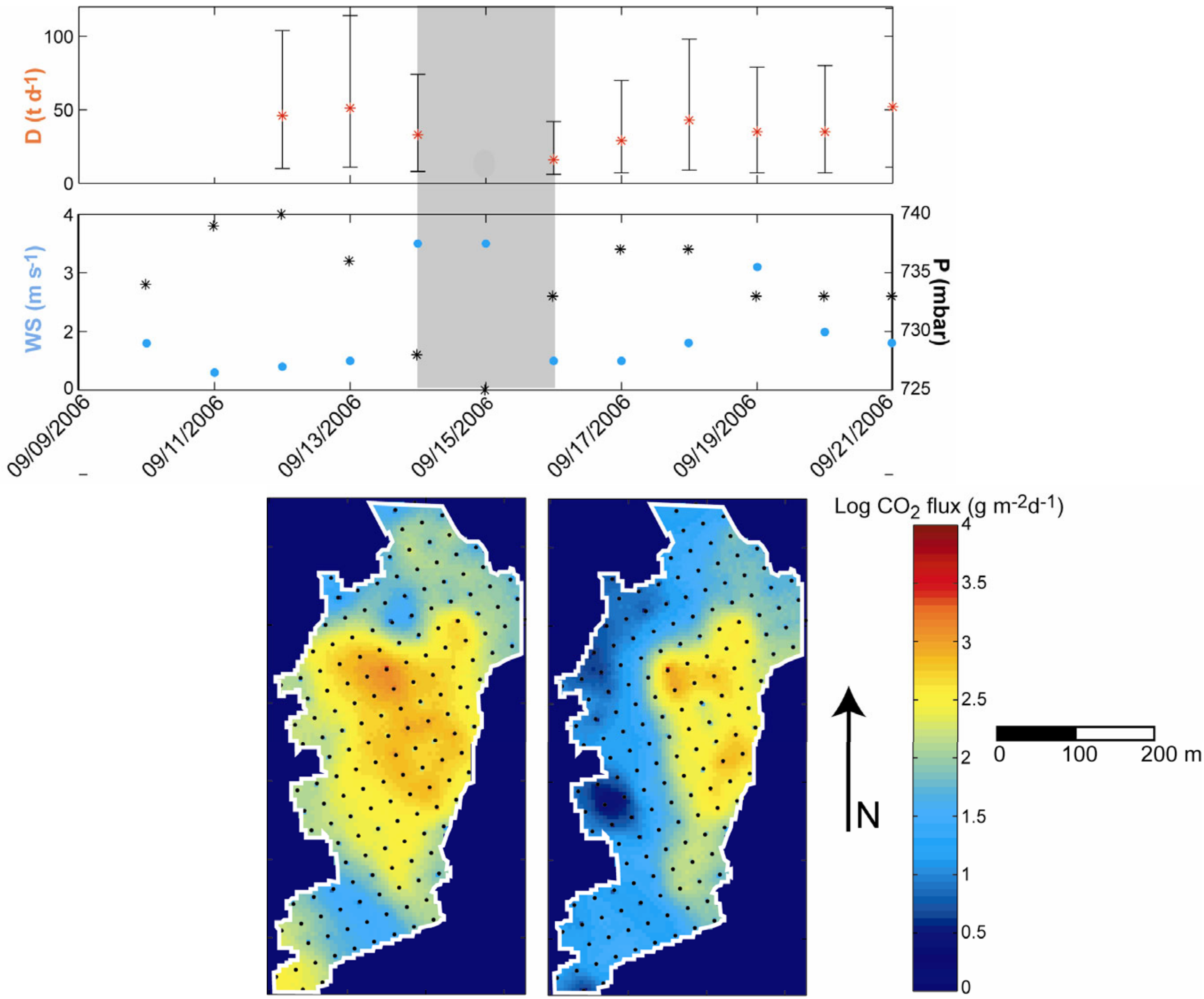

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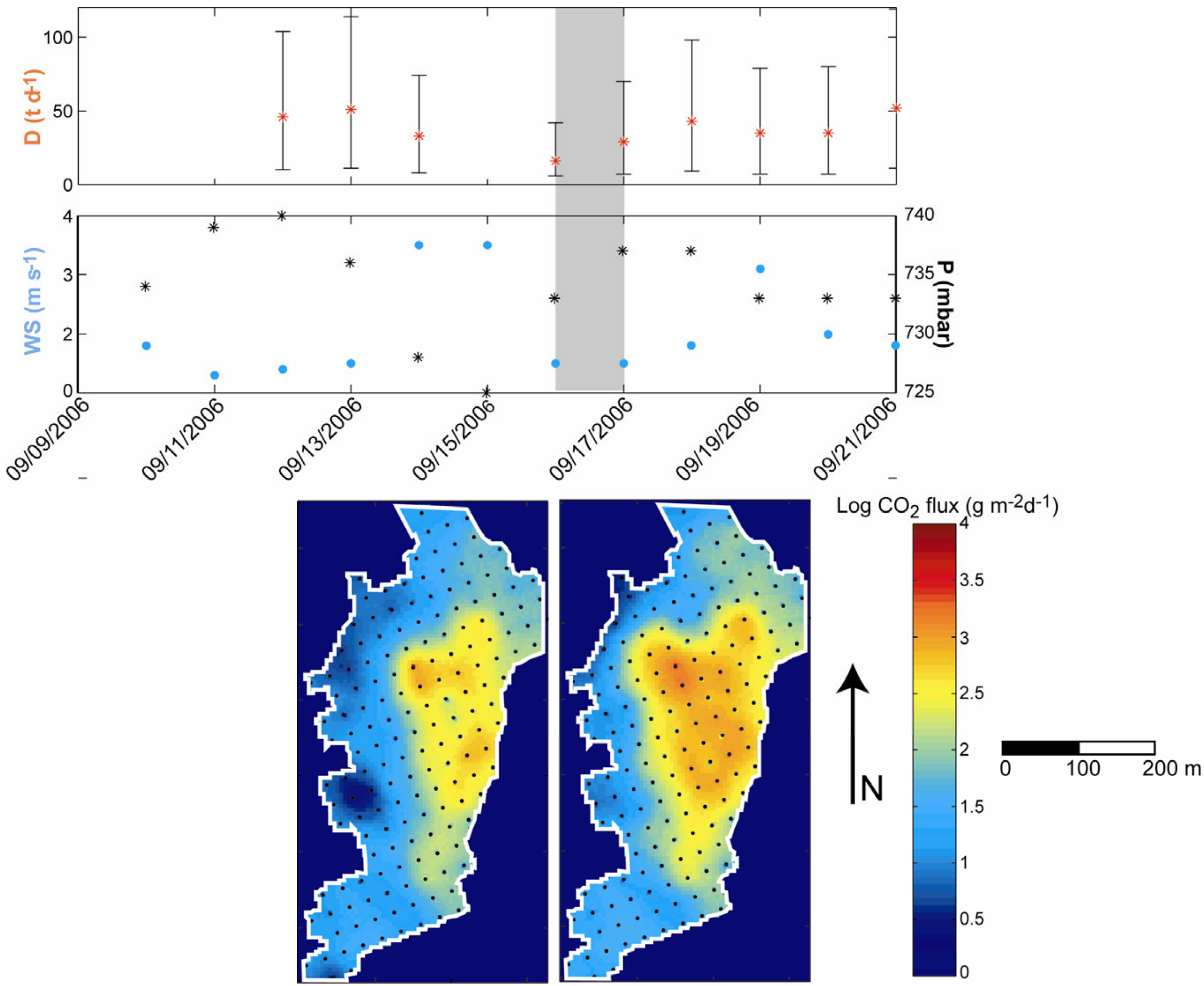

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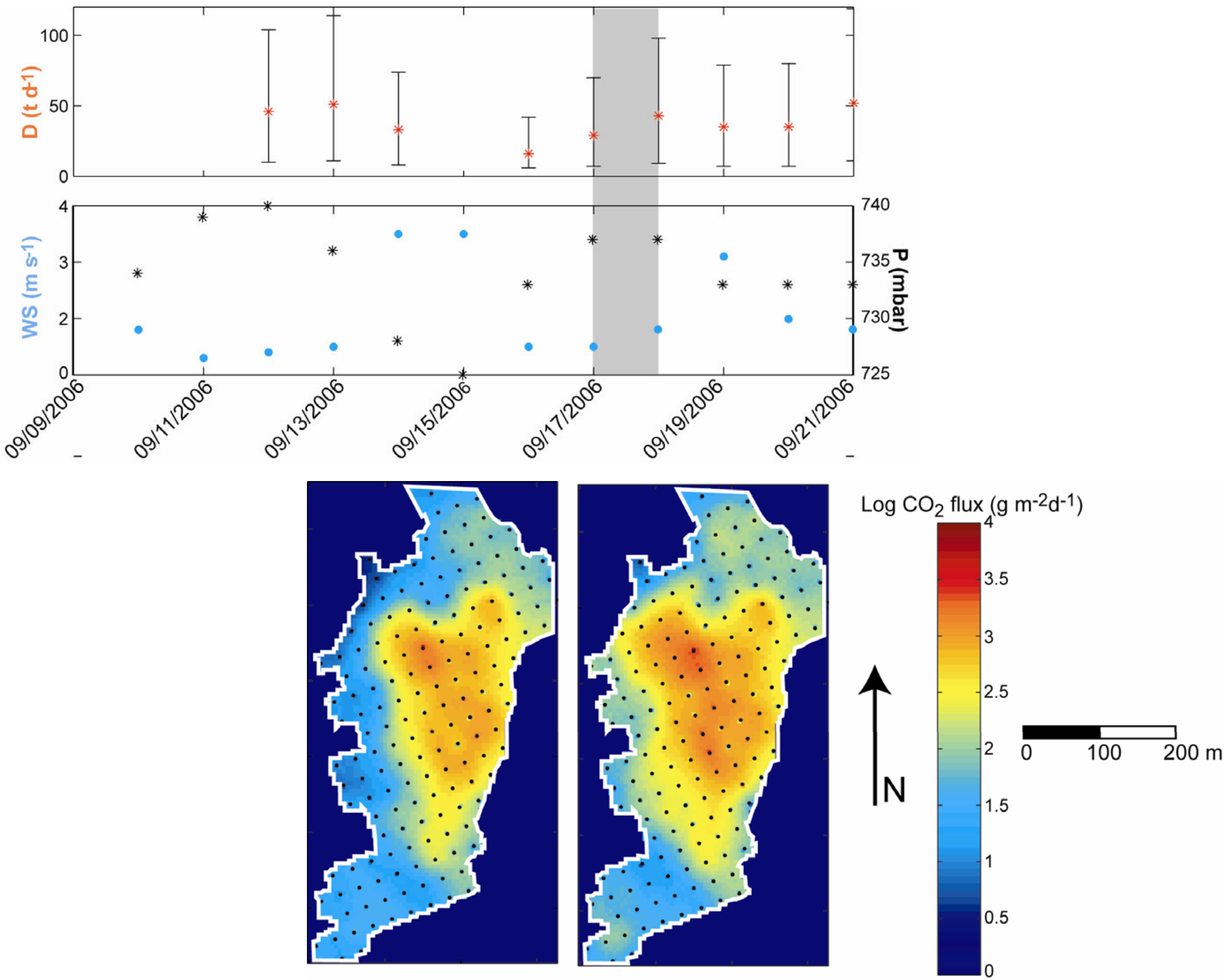
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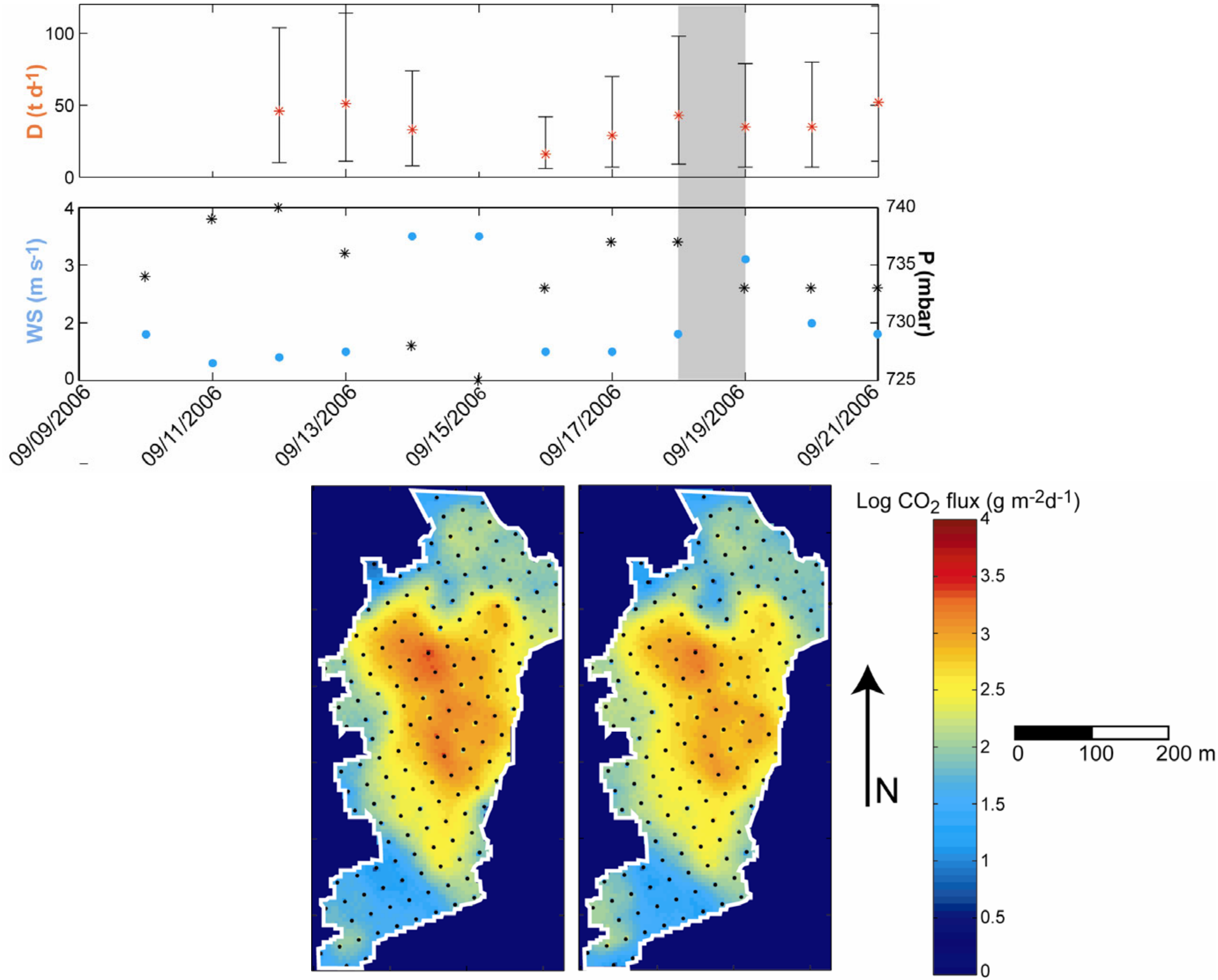

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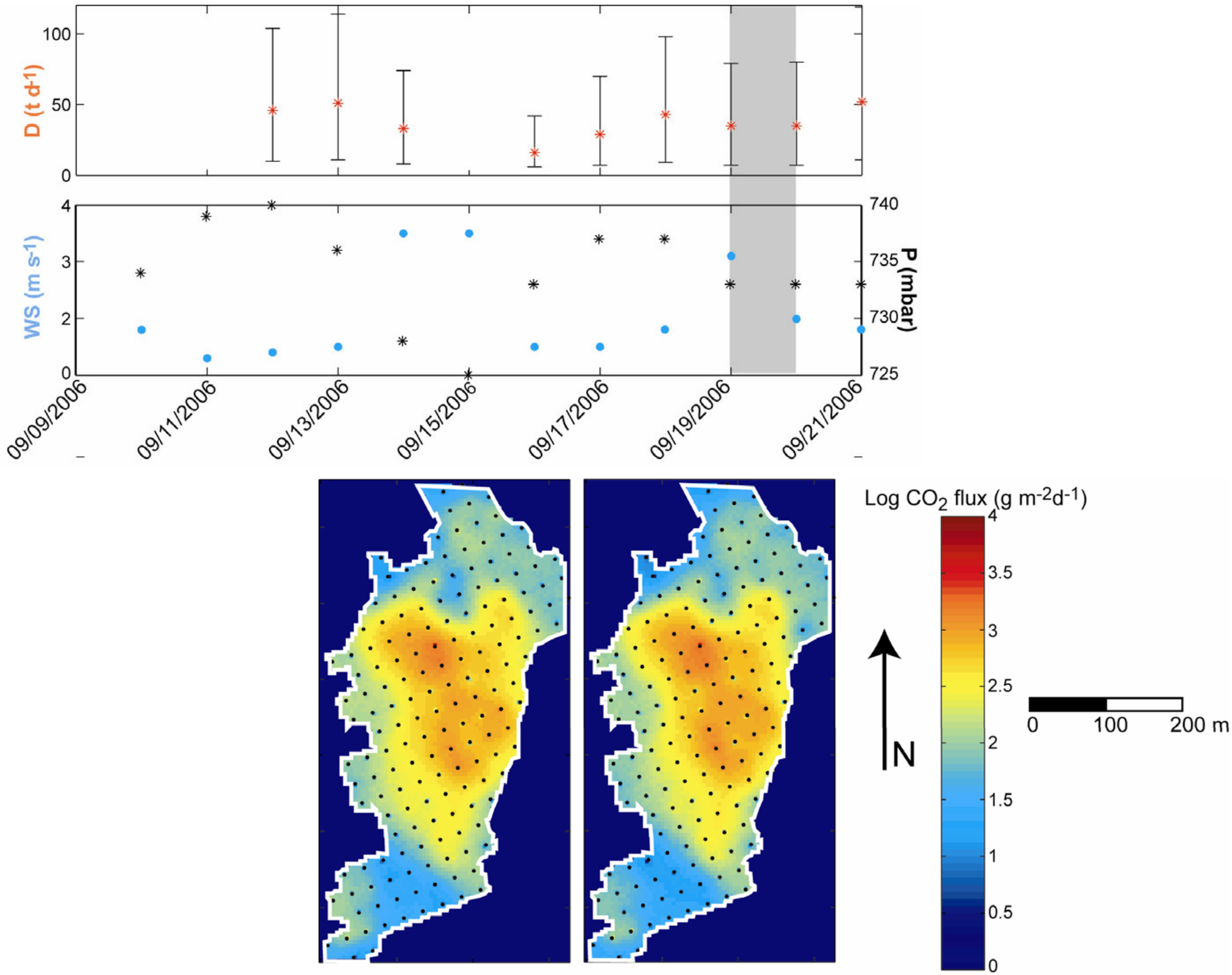

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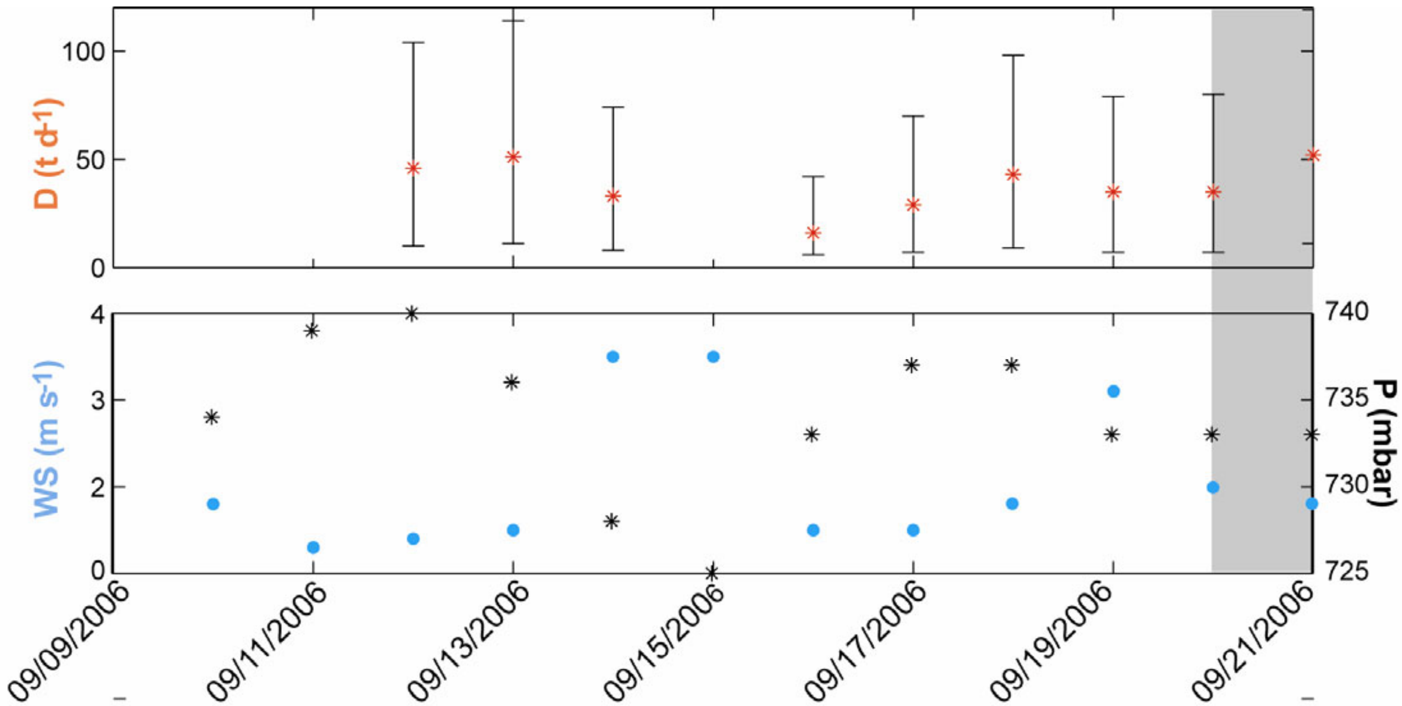
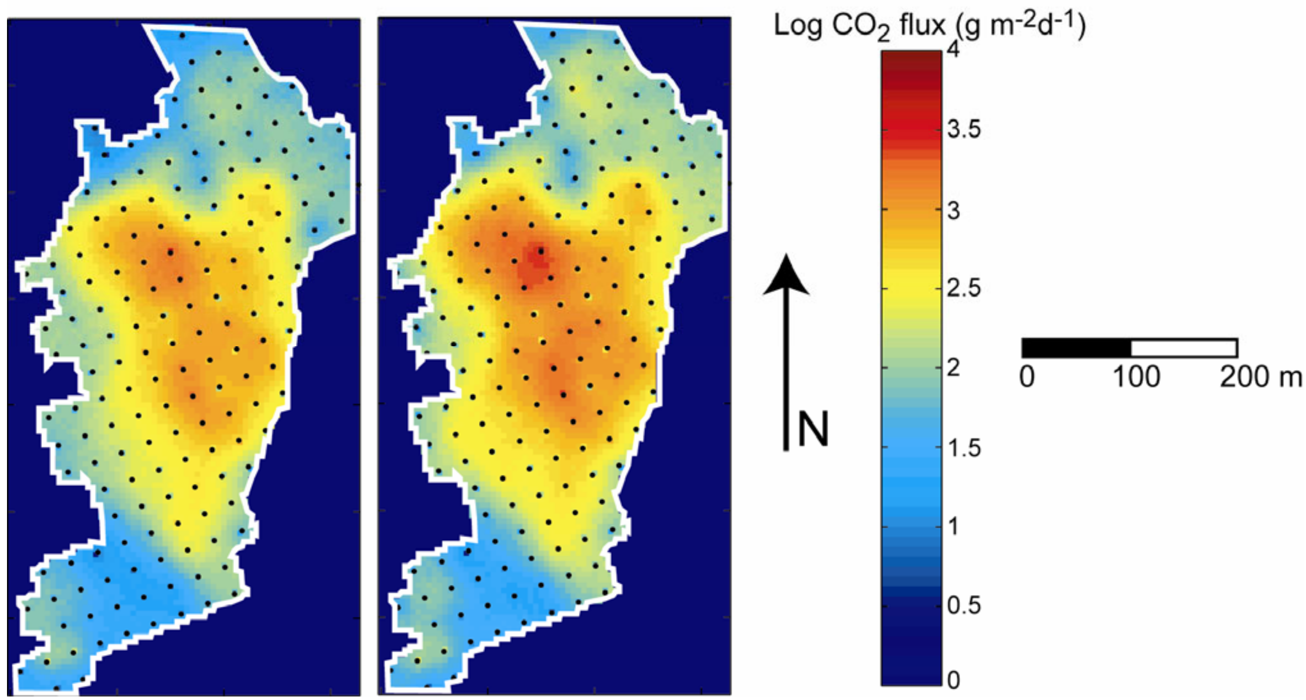
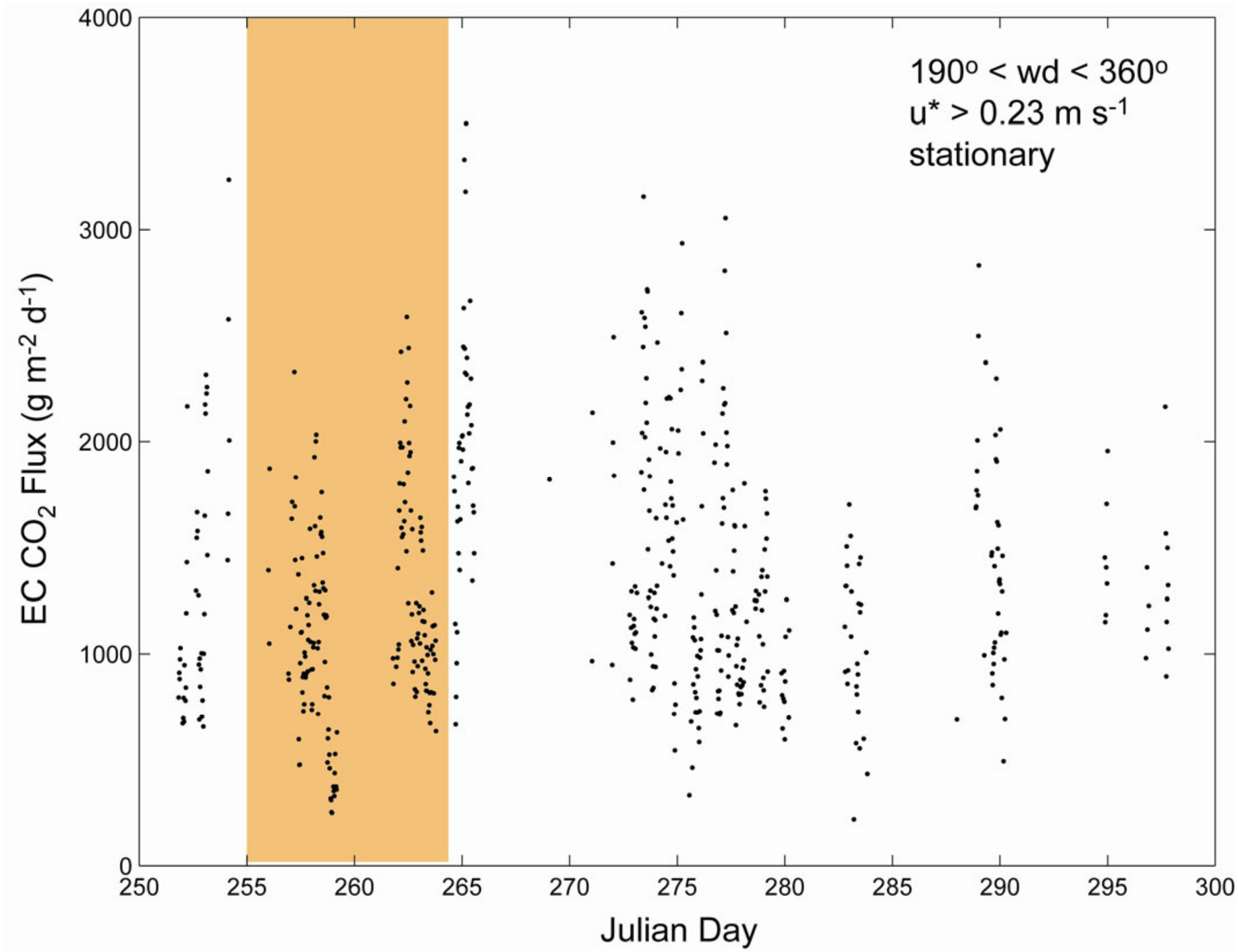


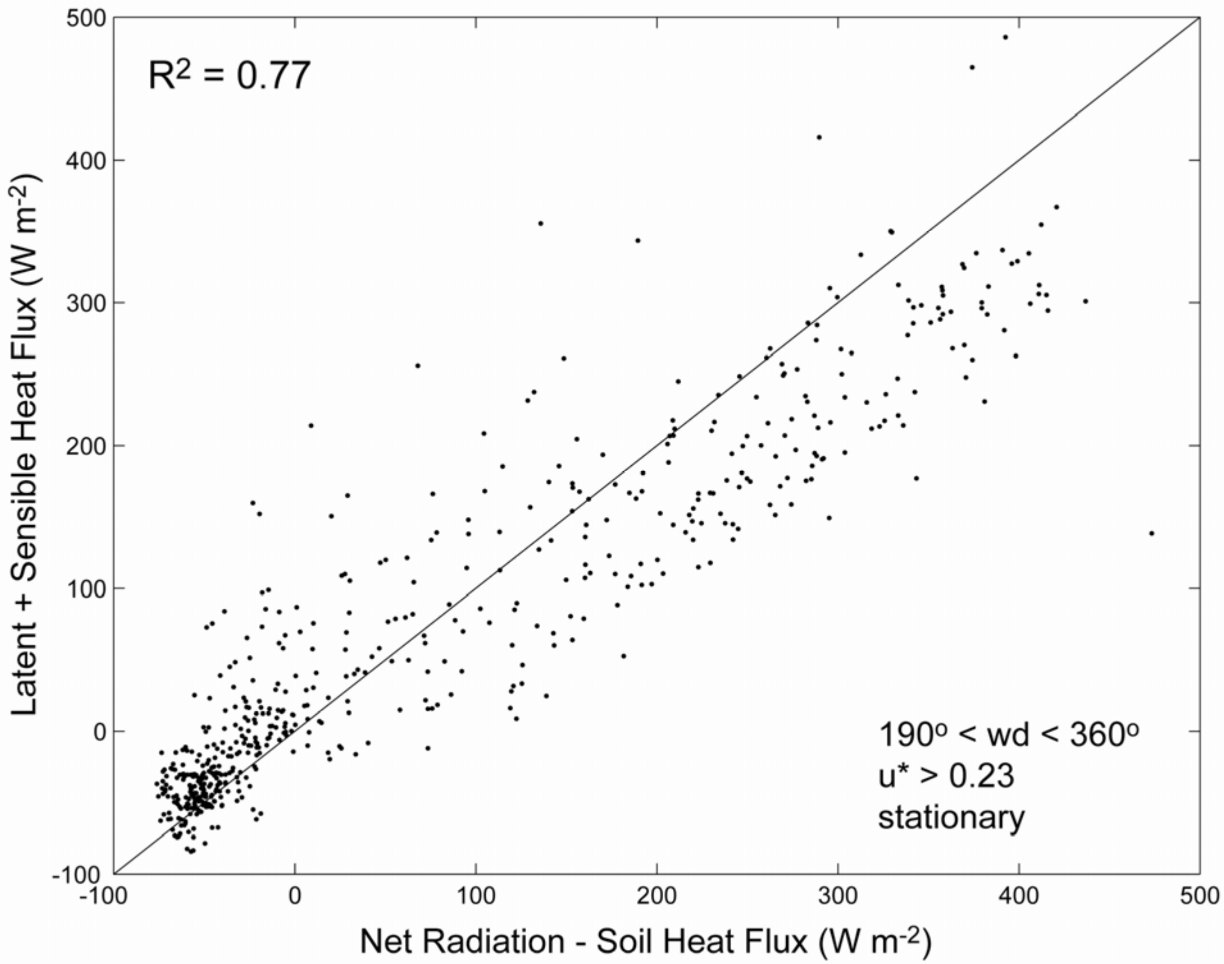


For further details, *Lewicki et al.*, *Geophysical Research Letters*, 2007 is available

Eddy Covariance Time Series



Energy Balance



Latent heat flux (LE) = F_{H2O} x latent heat of vaporization of water

- heat flux associated with evaporation (+) and condensation (-)

Sensible heat flux (H) = $\rho\ c_p\ \overline{T'w'}$

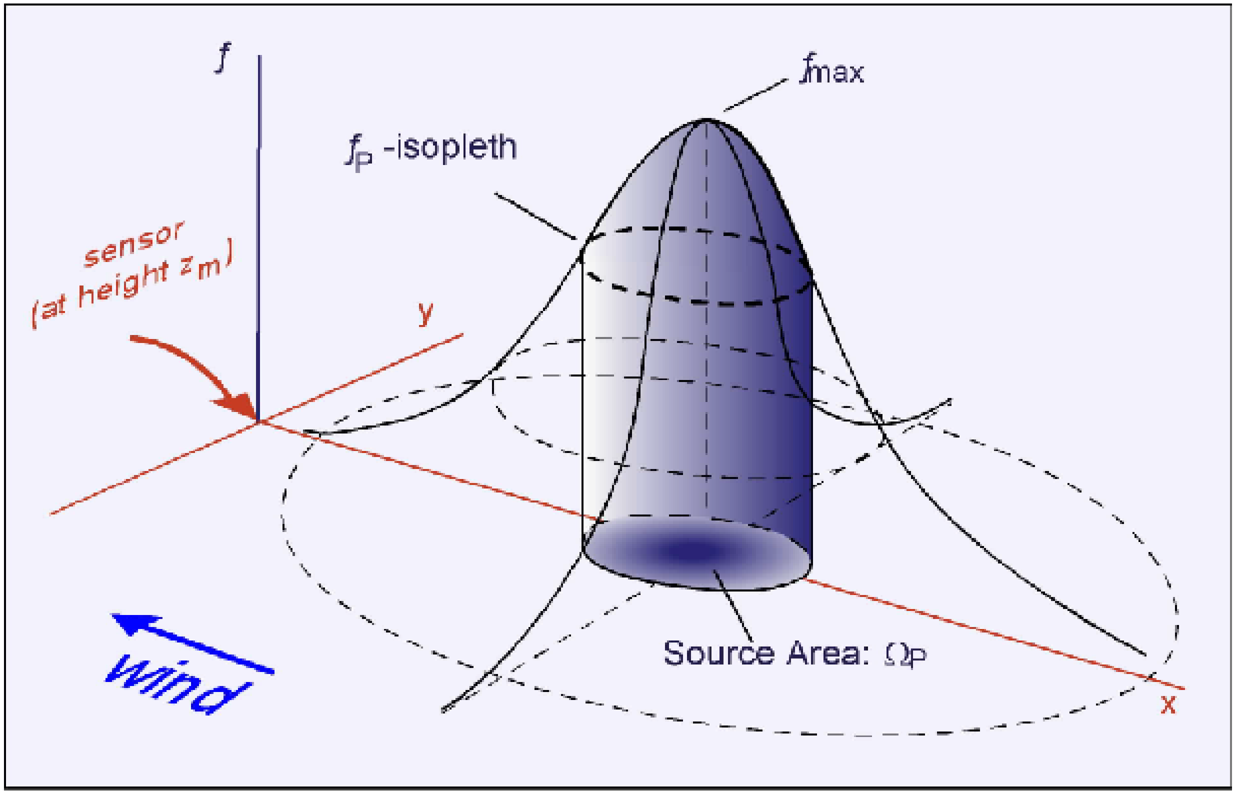
ρ = density dry air

c_p = heat capacity of water at constant P

T' = fluctuating sonic temperature

w' = fluctuating vertical wind speed

- heat flux associated with temperature gradient between surface and atmosphere (+ when surface is rel. warm, - when atm. is rel. warm)



EC Footprint

$$\eta(x_m, y_m, z_m) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} Q_\eta(x', y', z'=z_0)\cdot f(x_m - x', y_m - y', z_m - z_0)\cdot dx'dy'$$

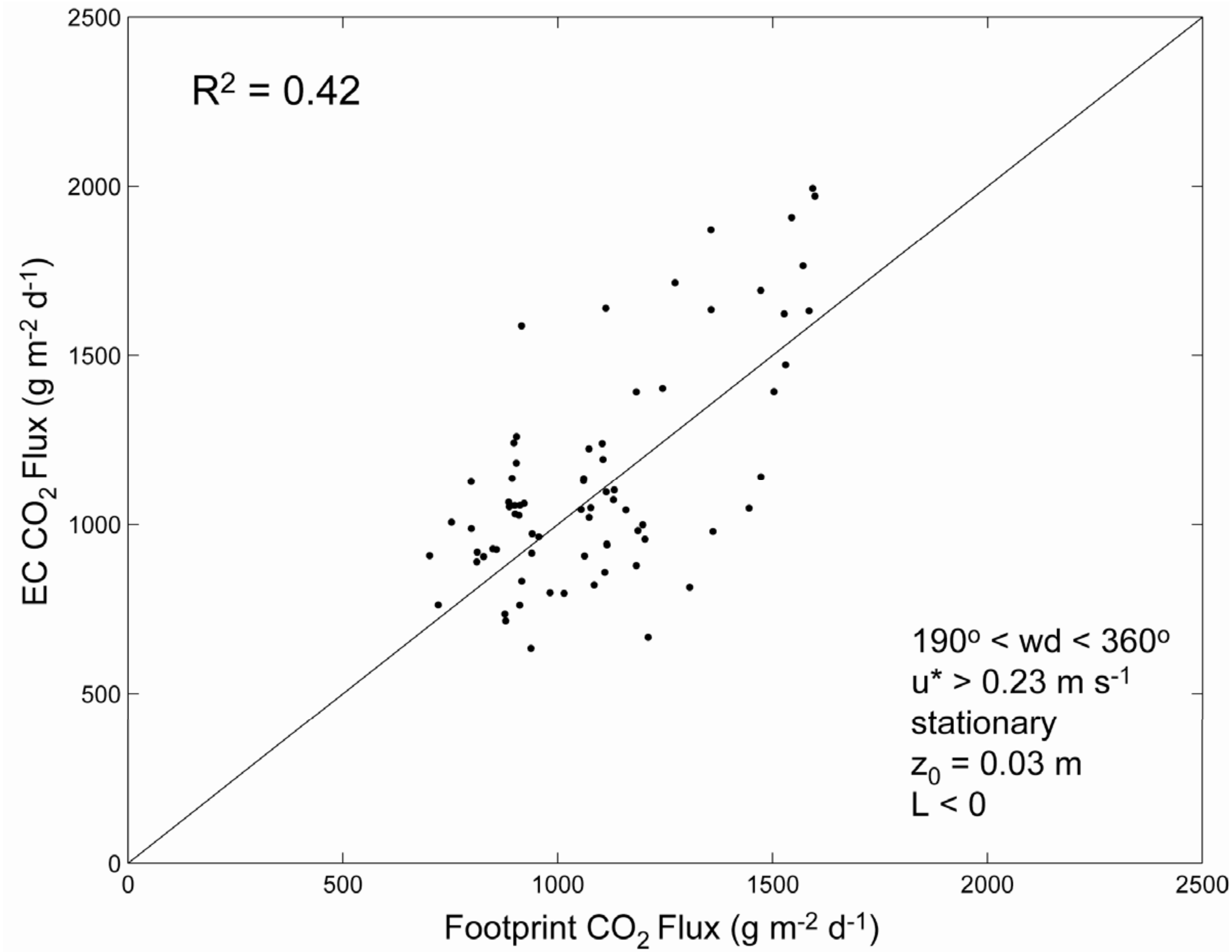
n = value of measured quantity (e.g., flux) at point (x_m, y_m, z_m) originating from the source at the surface ($x',y',z'=z_0$) with strength Q_n

f= the footprint (or source weight) function, a probabalistic weighting function that assigns a relative weight to each of the source strengths Q_n, depending on separation distance between the measurement and the source

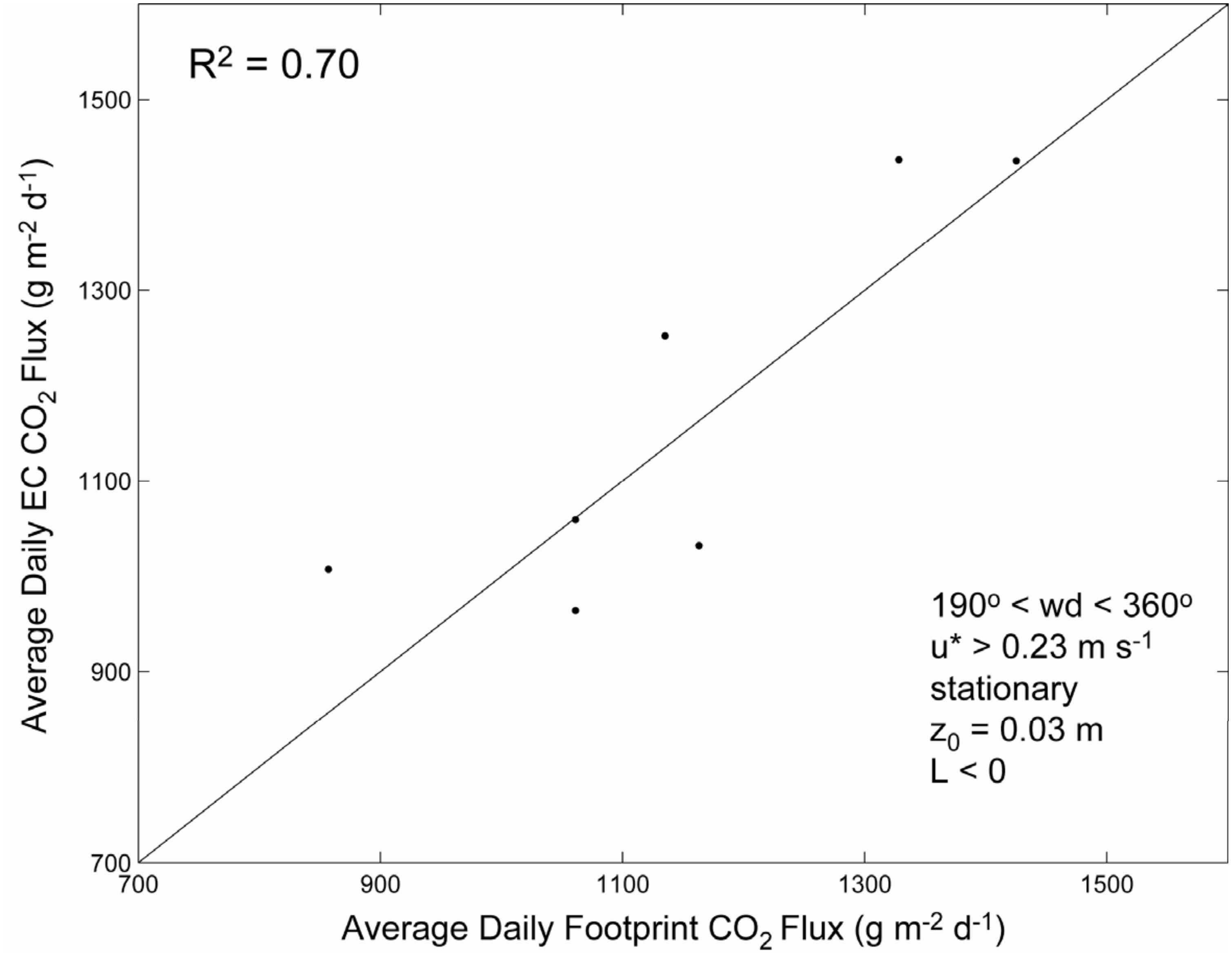
f is small for small separation distances, rises to a maximum with increasing distance, then falls off as separation is increased.

For fluxes, f is determined based on 2-D advection-diffusion equation. Depends on mean ws, direction, atmospheric stability, surf. rough.

Chamber-Eddy Covariance Comparison



Average Daily Flux Comparison



Summary

- Large, previously undocumented, spatio-temporal variations in soil CO_2 flux over multiple days associated with a weather front observed by AC method
- Potential effects of topography and meteorological parameters should be considered prior to the placement of continuous monitoring devices and interpretation of time series of data

Summary

- EC deployed at a site that challenged the basic assumptions of the measurement
- Based on energy balance closure, EC performed well.
- Moderate to good correlation between AC and EC fluxes based on footprint modeling observed

Summary

- Sources of error to consider in chamber-EC comparisons:
  - Heterogeneous CO_2 source distribution, complex terrain introduce error into EC measurement and footprint modeling.
  - Temporally varying source flux distribution difficult to capture with chamber measurements on time scales less than inter-daily.
- EC can be used to monitor surface fluxes in challenging environments, but data gaps must be tolerated. EC best used in conjunction with complementary AC method.

Thank you

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